

WHAT IS CLAIMED IS:

1 1. A process for combined thermal and catalytic treatment of heavy petroleum in a slurry
2 phase counterflow reactor, which process comprises:

3 a) introducing a liquid feedstock at a top of a reactor vessel to a gas phase
4 thermal reaction zone and thermally reacting said liquid feedstock;

5 b) injecting a gas comprising hydrogen near a bottom of said reactor vessel in
6 a catalytic reaction zone;

7 c) passing said liquid from said gas phase thermal reaction zone to a liquid phase
8 thermal reaction zone in said reactor vessel below and in communication with said gas-phase
9 thermal reaction zone and thermally reacting said reacted liquid therein;

10 d) passing said reacted liquid from said liquid phase thermal reaction zone to a
11 catalytic reaction zone below said liquid phase thermal reaction zone and chemically reacting said
12 reacted liquid therein; and

13 e) dispersing said hydrogen through said catalytic reaction zone, through said
14 liquid phase thermal reaction zone and through said gas-phase zone and thereafter separating said
15 hydrogen along with gaseous hydrocarbon products from said thermal and chemical reactions.

1 2. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including the additional steps of:

3 withdrawing heavy unconverted residual product from said bottom of said reactor
4 vessel;

5 directing at least a portion of said heavy residual product removed to a catalyst
6 addition system having a buffer tank; and
7 introducing catalyst to said reactor vessel from said catalyst addition system to said
8 catalytic reaction zone.

1 3. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 wherein said hydrogen gas is dispersed by injecting into said reactor vessel at said catalytic reaction
3 zone and bubbling said hydrogen gas through said vessel.

1 4. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 wherein said hydrogen gas is hot.

1 5. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including the additional step of encouraging mixing of said liquid in said liquid phase thermal
3 reaction zone through the use of a plurality of vertical baffles.

1 6. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including the additional step of filtering said withdrawing hydrogen gas with gaseous hydrogen
3 product through a filter to remove solids.

1 7. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including a liquid level detector to monitor the level of liquid in said liquid phase thermal reaction
3 zone in said reactor vessel.

4 8. A process for combined thermal and catalytic treatment as set forth in Claim 1
5 including the additional, initial step of passing said liquid feedstock in heat exchange with said
6 withdrawing hydrogen gas and hydrocarbon product to heat said liquid feedstock.

1 9. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 wherein said step of introducing liquid feedstock to a top of a reactor vessel is below a porous metal
3 filter screen.

1 10. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 wherein said step of introducing liquid feedstock at said top of said reactor vessel is through a
3 nozzle.

1 11. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including the additional step of separating said withdrawn hydrogen gas from said gaseous
3 hydrocarbon product and recirculating through said catalytic zone.

1 12. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 including controlling and monitoring pressure by a pressure let down system.

1 13. A process for combined thermal and catalytic treatment as set forth in Claim 1
2 wherein pressure in said reactor vessel is maintained at 1500-2000 PSIG and temperature is
3 maintained at 450°F-850°F.

1 14. A slurry phase counter flow reactor for combined thermal and catalytic treatment of
2 heavy petroleum, which reactor comprises:
3 a reactor vessel having a gas-phase thermal reaction zone, a liquid phase thermal
4 reaction zone, and a catalytic reaction zone;
5 a feedstock inlet in communication with said gas-phase thermal reaction zone;
6 a hydrogen-containing gas inlet in communication with said catalytic reaction zone;
7 an unconverted liquid and solid recovery outlet in communication with said catalytic
8 reaction zone; and;
9 a hydrogen-containing gas and gaseous hydrocarbon product outlet in communication
10 with said gas-phase thermal reaction zone.

1 15. A slurry phase counter flow reactor for combined thermal and catalytic treatment
2 petroleum as set forth in Claim 14 including a catalyst addition system.

1 16. A slurry phase counter flow reactor for combined thermal and catalytic treatment of
2 heavy petroleum as set forth in Claim 15 wherein said catalyst addition system includes an inlet in
3 communication with said liquid bottom product recovery outlet, a pump, a buffer tank, and an outlet
4 in communication with said catalytic reaction zone of said reactor.

1 17. A slurry phase counter flow reactor for combined thermal and catalytic treatment of
2 heavy petroleum as set forth in Claim 14 wherein said hydrogen-containing gas is substantially
3 hydrogen.

- 1 18. A slurry phase counter flow reactor for combined thermal and catalytic treatment of
2 heavy petroleum as set forth in Claim 14 wherein said hydrogen-containing gas is hot.